FY-2 AUTOMATIC LANDMARK POSITIONING FOR IMAGE NAVIGATION AND ITS APPLICATION IN FY-2D VISSR IMAGERY

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1. INTRODUCTION

The images of the Visible and Infrared Spin Scan Radiometer (VISSR) on board the FY-2 spin-stabilized geosynchronous meteorological satellites provide 1.25 km visible channel observations and 5.0 km IR channel observations. An accurate image navigation (i.e., conversion of the image line and pixel numbers into the latitude and longitude and vice versa) is an essential preprocessing for various operational applications for meteorology and oceanography of FY-2 VISSR data. The IN mainly depends on the satellite position, attitude, characteristics of the VISSR, and timing of the images. Those parameters can be calculated or directly measured, but there are still misalignments which produce the IN errors. The FY-2 IN accuracy is one IR pixel at SSP, which is to say $5-km$. Thus, as far as the visible channel is concerned, the IN accuracy is $2 \sim 3$ visible pixels in the south - north direction, and $4 \sim 5$ visible pixels in the west - east direction. This accuracy can be proved in the later analysis in this paper. So there is still some room for us to improve the IN accuracy for the visible channel. And various operational applications for meteorology and oceanography of FY-2 VISSR data require the imagery to be geometrically corrected.

Techniques exist which can geometrically correct the meteorological satellite images automatically. This is frequently accomplished by using offsets from known landmarks to determine corrections. Emery *et al.*[1] have proposed an automatic landmark matching algorithm based on maximum cross correlation (MCC). This method is for polar orbit earth observation satellite, and can not be applied in the geostationary orbit satellite[2]. Walter *et al.*[3] have proposed a GOES landmark positioning method, and can achieve sub-pixel IN accuracy. But they need a landmark template database which is from US Defense Mapping Agency. Thus, this has limited the method's application scope.

There are mainly three differences between our method and Walter's [3] method. First, we use an image in the NOM coordinates instead of the US Defense Mapping Agency (DMA) products. By this way, the researchers can use our method more freely. The second advantage is that [3] method only use islands and lakes as landmarks. Instead, our method is not limit to islands and lakes, the landmarks include the islands, lakes, rivers, coastline *et al.*. The third difference is that, our method use the t-test to choose the image matching coefficient. In this way, we can guarantee false image matching under a certain extent.

2. AUTOMATIC LANDMARK MATCHING ALGORITHM

Figure 1 is the steps of the proposed method. These steps will be explained in more details.

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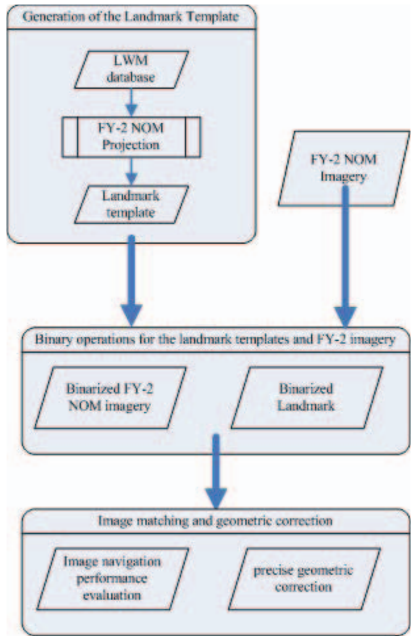

Fig. 1. Dataflow chart of the automatic landmark positioning algorithm for the FY-2.

2.1. Generation of the Landmark Template

Creating an accurately landmark base image is a crucial step towards the successful use of the the method. The landmark base image is consist of several landmarks with obvious features, such as islands, lakes, coastlines, rivers *et al.*. We use Land - Water Mask (LWM) database to extract landmarks. This database is from the International MODIS/AIRS Processing Package (IMAPP) which is developed at SSEC University of Wisconsin. The database is a 7 gray-level image with 1 km spatial resolution, and 0 for shallow ocean, 1 for land, 2 for ocean coastlines and lake Shorelines, 3 for shallow inland water, 4 for ephemeral (intermittent) water, 5 for deep inland water, 6 for moderate or continental ocean and 7 for deep ocean.

The base image must be registered to the exact same grid as the target images. Our aim is to geometrically correct the NOM imagey, so the base image must be registered to the NOM grid. If the satellite is on the idea geostationary orbit, the SSP is at the nominal position, the satellite spin axis is parallel to the line between the earth south - north pole, there are no misalignments for the VISSR, then the earth disk image obtained from the VISSR is called NOM. The projection is called the nominal projection. In fact, both satellite orbit and attitude are not at the ideal status. For the convenience of the users, we project the real satellite images into the NOM grid. Under such condition, the pixel line and sample number in the image are one-to-one correspondence with the geographic latitude and longitude.

2.2. Binary operations for the Landmark template and FY-2 imagery

By judging the landmark template gray-level, we can easily implement the landmark template into a binary image, and 1 for land, 2 for water. As far as the FY-2 imagery is concerned, we use Bayes posterior probabilities to transform the image pixel gray-level values to likelihood ratio values [3]. We denote L and W as land and water respectively. Given an image pixel gray-level value I, $P(L/I), P(W/I)$ are the posterior probabilities of L and W. $P(I/L), P(I/W)$ are conditional probabilities of I given L and W. Then, for the given image pixel gray-level value I, we have,

$$\rho(I) = \frac{P(L/I)/P(W/I)}{P(L)/P(W)} = \frac{P(I/L)}{P(I/W)} \tag{1}$$

where $\rho(I)$ is the normalized ration of posterior probabilities. And it measures the extent to which the pixel is land or water. If $\rho(I) \geq 1$, then the pixel is land. Otherwise, the pixel is water. In Equa. 1, $P(L)$ and $P(W)$ are the prior probabilities for L and W respectively. Under the assumption that the conditional probability distribution are Gaussian distribution, then we have the following equations:

$$P(I/L) = \frac{1}{\sqrt{2\pi\sigma_L}} e^{-\frac{(I-m_L)^2}{2\sigma_L^2}} \tag{2}$$

$$P(I/W) = \frac{1}{\sqrt{2\pi\sigma_W}} e^{-\frac{(I-m_W)^2}{2\sigma_W^2}} \tag{3}$$

where m_L, m_W are the mean values of the land and water pixels, σ_L, σ_W are the standard variations of the land and water pixels. After the binary operations for the landmark template and FY-2 imagery, the binary landmarks and binary FY-2 images are ready to match.

2.3. Image matching and geometric correction

Given binary landmark template and actual FY-2D imagery, we use image correlation to match the landmark and actual FY-2D imagery. Normalized Maximum cross correlation (NCC) is an effective way to find matches of a subimage $w(x, y)$ of size $J \times K$ within an image $f(x, y)$ of size $M \times N$, where we assume that $J <= M$ and $K <= N$. And NCC has already been successfully applied in the landmark matching[1]. It should be noted that only landmark without cloud contamination could be put into the MCC computation. To do this, we use a very strict cloud filter to avoid the cloud contamination. And NCC could generate many vector displacements, we use $t - test$ to eliminate false landmark matching.

Automatic landmark matching can be used to evaluate the FY-2 IN accuracy. And direct linear transformation (DLT) based on the automatic landmark matching can be put into improving the FY-2 IN accuracy. Although there exists strict mathematical formula to map the image line and sample coordinates into latitude and longitude coordinates, but we can used a more simple transformation called direct linear transformation (DLT) to get geometric corrections [2].

Table 1. IN accuracy before and after precise geometric correction (in VIS pixel: 1.25km)

	west - east	south - north
before correction	4.04	2.30
after correction	2.18	1.58

3. RESULTS AND DISCUSSION

Table1 is the average IN accuracy of 255 FY-2D images before and after the correction by applying the proposed method. FY-2D is located at $86.5°E$. The current IN accuracy is $4.04 - pixel$ and $2.30 - pixel$ in the west - east and south - north direction, respectively. That is to say, FY-2 IN accuracy is one IR pixel which is consistent with Lu *et al.* [4]. By applying the proposed precise geometric correction method, the IN accuracy have been achieved $2.18 - pixel$ and $1.58 - pixel$ respectively, which corresponds to 31.06% and 45.21% increase. FY-2 IN accuracy in the south - north direction is better than that of in the west - east. This is because FY-2 uses a dynamic earth edge detection procedure to calculate the roll component of the misalignment, and this misalignment is used to compensate the IN error in the south - north direction [4]. The west - east misalignment is compensated based on historical statistics, and does not work as well as that of the south - north direction. Therefore, the south - north direction IN error is much smaller than the west - east.

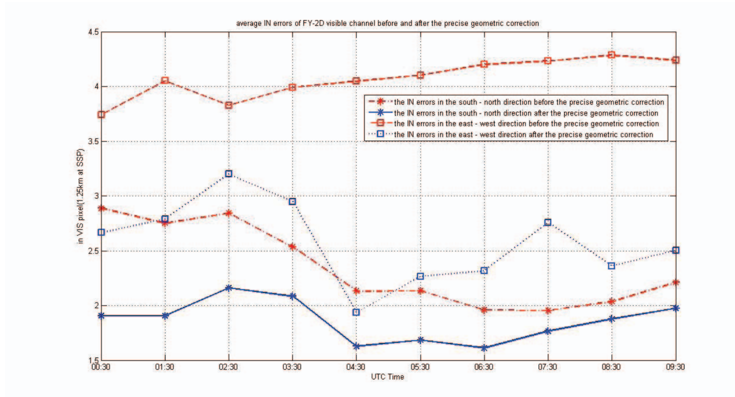

Fig. 2. IN errors before and after the precise geometric correction for the FY-2 visible channel.

Fig.2 is the FY-2D IN errors before and after the precise geometric correction. The y-axis is in VIS pixel (1.25km at SSP) and the x-axis is the UTC time. From Fig. 2, we can clear see that FY-2D IN accuracy can achieved its best status at SSP noon because of the adequate sunshine in both the west - east and south - north directions. With the high precision, the proposed method is ready to put into operation for FY-2 and will be further developed for FY-4.

4. CONCLUSIONS

We have proposed an automatic landmark positioning method for the FY-2 IN. And by applying this method, the FY-2 imagery can be geometrically precise corrected. By applying automatic landmark positioning method, we have proved that FY-2D IN accuracy is one IR pixel (5km) at SSP. We also have found that FY-2D south - north IN accuracy is better than that of the west - east. And the automatic precise geometric correction method can achieve at its best status at SSP noon due to sufficient sunshine condition. There are a few points to start future work. They include a detailed analysis of the FY-2 IN performance and extend the proposed method to IR channel.

5. REFERENCES

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